ESTIMATION OF THE PHYSIOLOGICAL PARAMETERS OF HEART-RATE AND OXYGEN-CONSUMPTION DURING HEAT AND WORK STRESS

Recep Mercankaya

NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

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Recep Mercankaya

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Stepwise mutliple regression was performed to attempt to find a mathematical model for heart-rate (beats per

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minute), and oxygen-consumption (liters per minute).

The models developed can be used to predict heart-rate and oxygen-consumption under varying thermal and workloads. Workload was found to correlate more strongly with heart-rate and oxygen-consumption than was heat level.

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by

Recep Mercankaya
Lieutenant (jg), Turkish Navy
Turkish Naval Academy, 1970

Submitted in partial fulfillment of the requirements for the degree of

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I. INTRODUCTION

The use of labor saving devices and the augmentation of the human's physical capacity by means of an expanding technology has altered the nature of the tasks man is called upon to perform in modern military systems. Generally, the role of the operator involves the monitoring and/or controlling of system functions and not active manipulation requiring the expenditure of substantial amounts of energy. There remains, however, tasks which, in the actual operation and/or maintenance of the system require that the operator be harnessed for the prupose of accomplishing mechanical work. These situations are often performed in environments less than optimum.

Considerable research has suggested that cardio-vascular and respiratory measures provide evidence of the organismic response to increased work levels and environmental influences (Manod, 1967, Sayers, 1973). However, these measures are non-specific in that they respond to a wide variety of physical, psychological, and environmental inputs, thereby making an accurate description of the input-output relationship difficult. In addressing this point, Wogt and Metz (1973) have suggested that heart-rate, the cardio-vascular measure most often employed as an index of the cost of physical activity, should be used only when the simultaneous influence of additional factors can be specified.

Energy for muscular activity can be supplied either by anaerobic processes, relying on oxygen stored in the body and resulting in the production of lastic acid and "fatigue," or by aerobic processes which occurs when oxygen intake balances the extra oxygen requirements for a given workload (Maitra and Koyal, 1971). The oxygen consumption that the body can process within a given time, depends on the respiratory and cardio-vascular system. Aerobic capacity is considered by authorities to be the best index of muscular capacity (Cooper, 1970).

Meyer, Metz and Foehr (1973) studied indirect estimation of intermittent muscular work and environmental heat loads. In their experiment, each subject performed four trials, each trial consisted of three workloads. These trials took place at 27°C and 35°C, and during each trial, heart-rate and rectal temperature were recorded. The result of their study indicated that heart-rate depends mainly upon the mechanical work performed.

Maitra and Koyal (1971) studied muscular fatigue of Bengalees with increasing workloads under different environmental conditions. In their study, the subjects were tested on an ergocycle in a hot humid environment (at 36°C with relative humidity 90%) and comfortable environment (at about 23°C with low humidity of 30%). The effects on ventilation, heart-rate, oxygen-consumption, blood lactate concentration were recorded.

The results of their study indicated that increasing workload (at constant heat level) produced fatigue by stressing cardiac activity to the limit; other parameters such as respiration, ventilation, glycogen utilization, etc. still had some reserve power at the exhaustion level during the muscular activity.

The studies discussed above indicate that workload and environmental inputs (e.g., heat) result in responses in the cardio-vascular and respiratory systems. These responses are generally interpreted as an indicants of the strain the organism is undergoing as a result of the input. As such, it would be advantageous if a method existed in which the strain an individual was going to experience as a result of being subjected to various work and environmental conditions could be predicted.

The present paper represents an attempt to model the physiological parameters of heart-rate and oxygen-consumption for the purpose of providing an instrument for the prediction of strain.

II. METHOD

A. APPARATUS

The equipment used during the course of this experiment can be grouped into three general categories: (1) equipment used to produce mechanical work; (2) equipment used to record oxygen-consumption; and (3) equipment required to record heart-rate.

1. Recording Heart-Beat

A Dynograph with type 9854 heart-rate coupler was used to record heart-beats. Heart-beat was recorded on chart paper at a chart speed of five milimeters per second. To reduce the body movement effects, the filter switch on the Dynograph was set up to pass frequencies up to 30 Hz. Electrodes used were Beckman type G50418 skin electrodes. A total of three electrodes were applied to each subject. One electrode was placed below the left breast at the sixth intercostal space; one electrode was placed at the top of the sternum; and a ground electrode attached over the right hip. Prior to the placing of the electrodes, the skin was cleaned using rubbing alcohol. Beckman Offner electrode paste was placed in each electrode cup to minimize resistance, and attached to the subjects by means of Beckman adhesive applicators.

2. Obtaining Mechanical Work

A stationary bicycle ergometer was used to monitor the mechanical work task. This ergometer possessed an electronic system that had the capability of measuring the user's pulse rate per minute, crank revolutions per minute, and workload in the kilo pound per minute.

3. Recording Oxygen-Consumption

Oxygen-consumption was determined as follows:

Oxygen consumption = (% oxygen in chamber - % oxygen in expired air) x (volume of expired air).

The volume of exhaled air was measured in liters by using a "Respiration Gasmeter." It was also utilized to sample the expired air required for determing the percent of oxygen used. The sampling rate was set at six percent of the total amount of expired air during the trial. The respiration device measures volume in liters. A small rubber "sack" was used to transfer the expired air to an "Oxygen Analyzer."

B. TEST SITE AND SUBJECTS

The experiment was conducted in the Human Engineering and Man-Machine Systems Laboratory of the Naval Postgraduate School, Monterey, California. The bicycle ergometer and respiration gasmeter were placed on an acoustic-temperature controlled chamber. Heat level in the chamber was controlled automatically by setting the switch on the desired heat

level. The range of the heat that can be obtained by the chamber is (20°F - 120°F).

There were a total of four healthy subjects, all male officer students at the Naval Postgraduate School. Subjects were selected from the volunteers. The ages of the subjects varied between 25-27, weights varied between 155-185 lbs., and heights varied between 5 ft. 6 in. - 6 ft.

C. PROCEDURE

Before the subjects were prepared and hooked up to the apparatus, they were given a brief explanation of the experiment. Each subject was told he could observe his instantaneous heart-rate during the task session by looking at the "heart-rate" meter which was located on the ergocycle. Each subject performed four trials, each trial was separated two weeks to control for climatization. The sequence of the trials were performed in the following manner:

1st trial was at 65°F

2nd trial was at 75°F

3rd trial was at 85°F, and the

4th trial was at 95°F.

Each trial consisted of four mechanical task sessions, and sequence of the sessions performed were:

1st task was performed at 30 rpm or 780 KPM/min

2nd task was performed at 40 rpm or 1120 KPM/min

3rd task was performed at 50 rpm or 1320 KPM/min

4th task was performed at 60 rpm or 1535 KPM/min.

Each work-task cycle of 5 minutes duration was followed by 5-8 minute rest period. After a brief explanation of the experiment to each subject, electrodes were placed on the subject's chest and the gas collection mask fitted to each subject. Then the subjects were taken to the heat chamber, and seated on the ergometer bicycle seat. During the experiment the subjects wore only shorts and tennis shoes.

It was found that subjects couldn't fix the work level by looking at the kilo pound per minute (KPM/min) meter on the ergocycle. To get the exact work level, an "RPM" meter was used. Each subject was told to maintain speed by observing the crank-revolution meter (rpm). The amount of work was set at 30, 40, 50, 60 rpm, and these were converted to the kilo pound per minute (KPM/min).

Subjects were instructed to discontinue the experiment if they felt extreme discomfort.

D. COLLECTION AND REDUCTION OF DATA

In this experiment four different heat loads, and four different workloads were used. Heat loads were 65°F, 75°F, 85°F, 95°F, and workloads were 780, 1120, 1320, 1535 KPM/min (kilo pound per minute). For each trial, the subject's heart-beat (beats per minute), volume of exhaled air (liter per min), % of oxygen in heat chamber, and % of oxygen in exhaled air were recorded. At the conclusion of the experiment, the following data had been obtained: 64 electrocardiagram rate traces, 66 expired air volume, 64 data points for % oxygen in heat chamber, and 64 data points % oxygen in

the exhaled air. The mean heart-rate was computed by counting the number of R wave peaks during the last minute of each period. Oxygen intake was computed as follows:

(% oxygen in chamber - % oxygen in expired air) x (volume of expired air in liters) = oxygen-consumption in liters.

III. STATISTICAL ANALYSIS AND RESULTS

Two statistical analyses were performed; (1) to produce mathematical model for heart-rate and oxygen-consumption, and (2) to test the differences between work and heat levels on heart-rate and oxygen-consumption.

1. Producing Mathematical Models

Stepwise multiple regression was employed in attempting to develop a mathematical model. Data included: heart-rate, oxygen-consumption, heat level and workload. In the stepwise program two general models were used to see which model gave the best linear fit to the data (higher multiple R value indicates best linear fit) to determine heart-rate and oxygen-consumption under varying heat and workload.

Model I: (Heat Level) and (Work Level) were used as an explanatory variable.

Model II: (Heat Level) and (Work Level) were transgenerated to the $(\text{Heat Level})^{\frac{1}{2}}$, $(\text{Work Level})^{\frac{1}{2}}$, $(\text{Heat Level})^{2}$ and $(\text{Work Level})^{2}$. In stepwise multiple regression computer program, F level for inclusion 0.5, F level for deletion 0.3, and tolerance level 0.001 were used.

For both Model I and Model II the sequence of variables to enter these models are associated multiple R values were produced (see Table I) by using the stepwise regression. Model II produced higher multiple R values. Therefore, Model II which has transgenerated variables was used to estimate heart-rate and oxygen-consumption.

Explanatory variables in Model II were tested for significance level, $0.001 \leq P < 0.20$ model for oxygen-intake was $Y = 0.7099 + 2.10^{-7}(\text{Work Level})^2$, and for $P \geq 0.20$, $Y = 3.45 - 0.001(\text{Work Level})^{1/2} - 0.059(\text{Heat Level}) + 0.0004 (\text{Work Level})^2$ (see Table IIA).

Models for the heart-rate were: $Y = 57.13 + 0.0071 (\text{Heat Level})^2 + 0.0002(\text{Work Level})^2$ for $0.001 \leq P < 0.005$, $Y = 320.69 - 39.67(\text{Heat Level})^{1/2} + 0.0159(\text{Heat Level})^2 + 0.00002(\text{Work Level})^2$ for $0.005 \leq P < 0.025$, and $Y = 359.92 - 0.062(\text{Work Level}) - 39.65(\text{Heat Level})^{1/2} + 0.0159(\text{Heat Level})^2 + 0.0004(\text{Work Level})^2$ for $P \geq 0.025$ (see Table IIB).

2. <u>Testing the Differences Between Work Levels and Heat Levels Effecting Heart-Rate and Oxygen-Consumption</u>

Common slope t-test (see Appendix A) was used to compare heart-rate and oxygen-consumption for each level of heat and each level of work.

The results of common slope t-test indicated that for significance level P = 0.01, there is a difference between each work level (780, 1170, 1370, 1535 KPM/min), affecting the heart-rate, and for significance level P = 0.25, there is each heat level (65, 75, 85, 95°F) affecting heart-rate (see Table IIIA, IIIB). Also slope t-test indicated that effecting on oxygen-consumption each work level were different at significance level P = 0.25, and each heat level were different at significance level P = 0.05 (see Table IIIC, IIID and Figure IB, IIB). To use common slope t-test, linear regression models were produced by using

the "REGRE" computer program. Stepwise regression was utilized to find the correlations for both heart-rate and oxygen-consumption with their explanatory variables (see Table V, VI). The results indicated that $(\text{Work Level})^2$ has the highest correlation for both heart rate and oxygen consumption.

IV. DISCUSSION

To assign a subject to work in a hot environment requires physical fitness which can be explained by the physiological parameters: heart rate and oxygen consumption. In this research, these two parameters were formulated in terms of heat and workloads at constant level humidity and constant ventilation conditions.

Mathematical models were produced by fitting the data to the multiple regression model using the stepwise procedure. Models were produced and tested for significance. These models for a given significance level may have possible use predicting physiological response under heat and workload.

For significance level P = 0.05 estimated heart-rate and oxygen-consumption were compared with the actual values of heart-rate and oxygen-consumption that were collected during the experiment. In the stepwise multiple regression model, two modeling processes were tried, and Model II which has transgenerated variables, has higher multiple R values (shows the best linear fit). From Model I and Model II estimated values of heart-beat and oxygen-consumption were compared (see Table VII, VIII). Model I which has transgenerated variables, gave close estimates for the actual values of heart-rate and oxygen-consumption. Both models were consistent with the result that (work level)

has higher priority (first entered the models) to define the physiological parameters heart rate and oxygen consumption. The increase of muscular activity causes an increase in oxygen consumption and an increase in heart-rate. The energy for the muscular activity can be supplied either by anaerobic process with the accumulation of lactic acid, or by aerobic process when oxygen-intake balances the extra oxygen requirements. This was indicated in the result of stepwise regression model which showed that work level has higher priority (first entered the model) to define the heart-rate and oxygen-consumption.

For the constant heat level and constant work level, linear models were transgenerated for both heart-rate and oxygen-consumption. These models can be used to estimate these physiological parameters. In this research the models were tested for the hypothesis: "is there a significant difference between each heat level under the same workload, and significant difference between each work level under same heat level, effecting on heart-rate and oxygen-intake"?

Results of the analysis indicated that at significance level P = 0.025, there is a difference between each heat level (65, 75, 85, 95°F), and difference between each workload (780, 1120, 1370, 1535 KPM/min) effecting on heart-rate and oxygen-consumption.

Table I. Sequence of the Variables Enter the Models.

Model I: (Heat Level) and (Work Level) were used as an explanatory variables to estimate heart-rate and oxygen-consumption.

Dependent Variable	Independent Variable	Multiple R	Test Statistics F
Oxygen-Intake	$(\text{Work Level})^2$	0.69	59.02
	$(\text{Heat Level})^2$	0.70	1.93
	(Heat Level)	0.72	3.22
	$(\text{Work Level})^{1/2}$	0.72	0.14
Heart-Beat	$(\text{Work Level})^2$	0.85	162.33
	$(\text{Heat Level})^2$	0.86	25.02
	$(\text{Heat Level})^{1/2}$	0.91	8.69
	(Work Level)	0.92	6.80

Model II: (Heat Level) and (Work Level) were Transgenerated to the $(\text{Heat Level})^{1/2}$, $(\text{Work Level})^{1/2}$, $(\text{Heat Level})^2$ and $(\text{Work Level})^2$.

Dependent Variable	Independent Variable	Multiple R	Test Statistics F
Oxygen-Intake	(Work Level)	0.69	56.82
	(Heat Level)	0.69	0.77
Heart-Beat	(Work Level)	0.76	190.37
	(Heat Level)	0.83	19.86

Table IIA. Mathematical Models for Oxygen-Intake.

P	F	Mathematical Models for Oxygen-Intake
0.001	11.97	$Y = 0.7099 + 2.10^{-7}(\text{Work}\cdot L)^2$
0.005	8.49	"
0.01	7.08	"
0.025	5.29	"
0.05	4.0	"
0.20	1.7	$Y = 3.245 - 0.001(\text{Work}\cdot L)^{\frac{1}{2}} - 0.059(\text{Heat}\cdot L)$ $+ 0.004(\text{Heat})^2$

P = Level of Significance

F = F-test Value

Table IIB. Mathematical Models for Heart-Beat

P	F	Mathematical Models for Heart-Beat
0.001	11.97	$Y = 57.13 + 0.0021(\text{Heat}\cdot L)^2 + 0.00002(\text{Work}\cdot L)^2$
0.005	8.49	$Y = 320.69 - 39.67(\text{Heat}\cdot L)^{\frac{1}{2}} + 0.0159(\text{Heat}\cdot L)^2 + 0.0002(\text{Work}\cdot L)^2$
0.01	7.68	"
0.025	5.29	$Y = 354.92 - 0.062(\text{Work}\cdot L) - 39.65(\text{Heat}\cdot L)^{\frac{1}{2}} + 0.0159(\text{Heat}\cdot L)^2 + 0.0004(\text{Work}\cdot L)^2$
0.05	4.0	"
0.10	2.79	"

P = Level of Significance

F = F-test Value

Table IIIA. Comparison Heat Levels effecting Heart-Rate.

Overall Work Level	Comparison of Heat Levels	Vd	$t_{(computed)}$	$t^{(.95)}_{n_1+n_2=178}$	Difference Between Treatments at α=.05
	Heat level 95°F vs. Heat level 85°F	.0042	.71	1.658	NO
	Heat level 95°F vs. Heat level 75°F	.0038	3.42		YES
	Heat level 95°F vs. Heat level 65°F	.0035	1.72		YES
HEART-BEAT (Beats per minute)	Heat level 85°F vs. Heat level 75°F	.004	2.5		YES
	Heat level 85°F vs. Heat level 65°F	.0037	1.09		YES
	Heat level 75°F vs. Heat level 65°F	.0033	2.42		YES

Vd: test statistics value (see Appendix A)

Table IIIB. Comparison Work Levels Affecting Heart-Rate.

Overall Heat Level	Comparison of Work Levels (KPM/min)	Vd	$t_{(computed)}$	$t^{(.95)}_{n_1+n_2=128}$	Difference In Treatments at α = .05
	Work level 1535 versus Work level 1320	.10	3.35	1.658	YES
	Work level 1535 versus Work level 1120	.054	3.8		YES
	Work level 1535 versus Work level 780	.076	3.15		YES
HEART-BEAT (Beats per minute)	Work level 1320 versus Work level 1120	.01	1.5		NO
	Work level 1320 versus Work level 780	.093	5.35		YES
	Work level 1120 versus Work level 780	.003	1.8		YES

Vd: Test statistic value (see Appendix A)

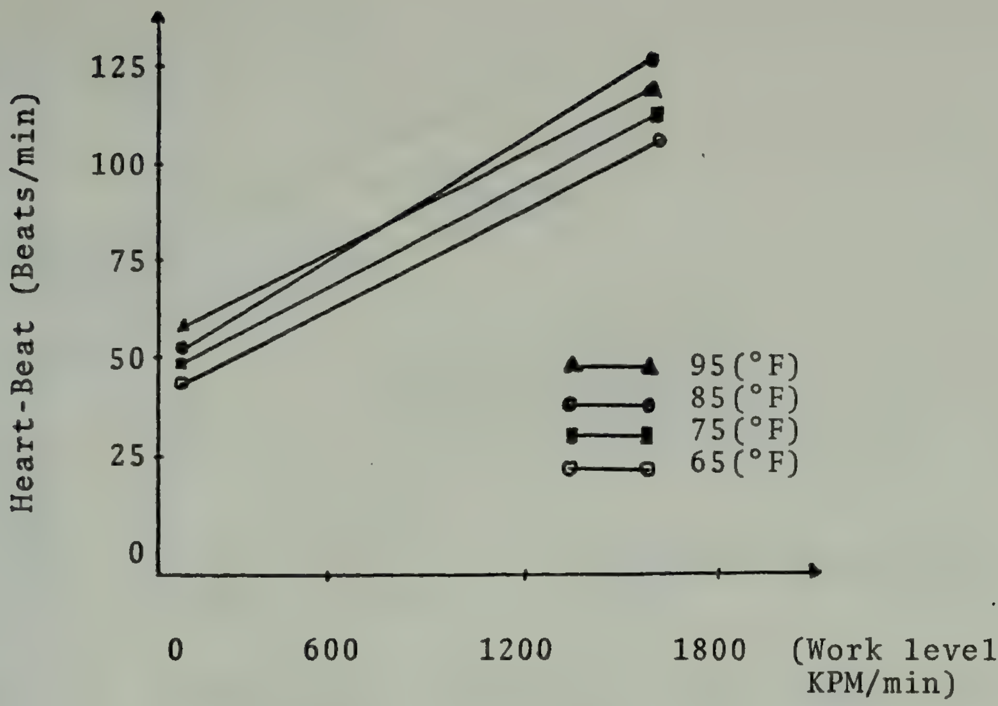

Figure IA. Linear models for mean response heart-beat for constant heat-levels.

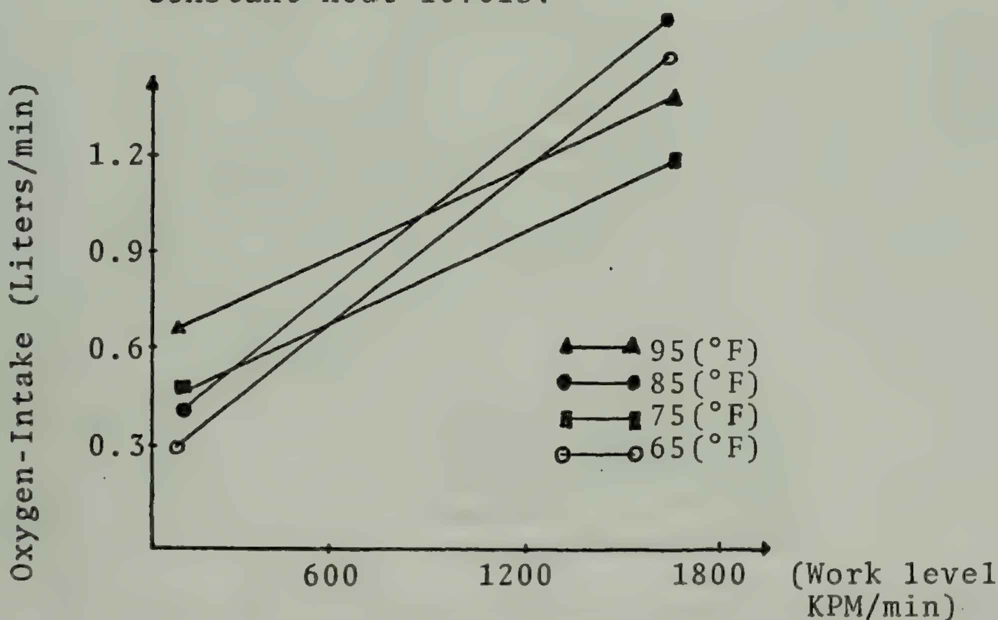

Figure IB. Linear models for mean response oxygen-intake for constant heat levels.

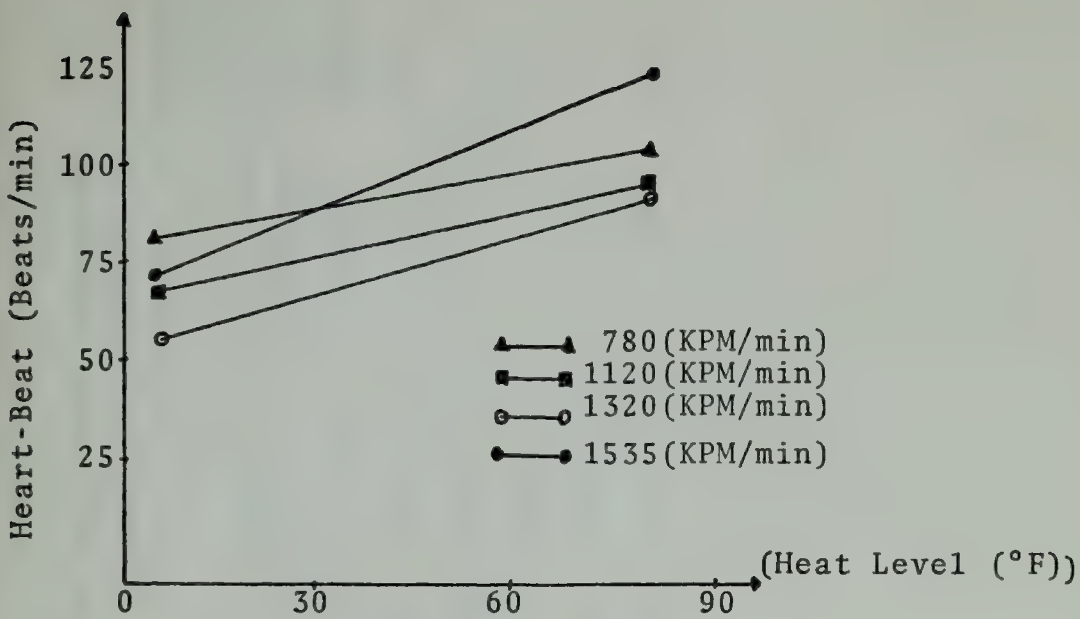

Figure IIA. Linear models for mean response heart-beat for constant work levels

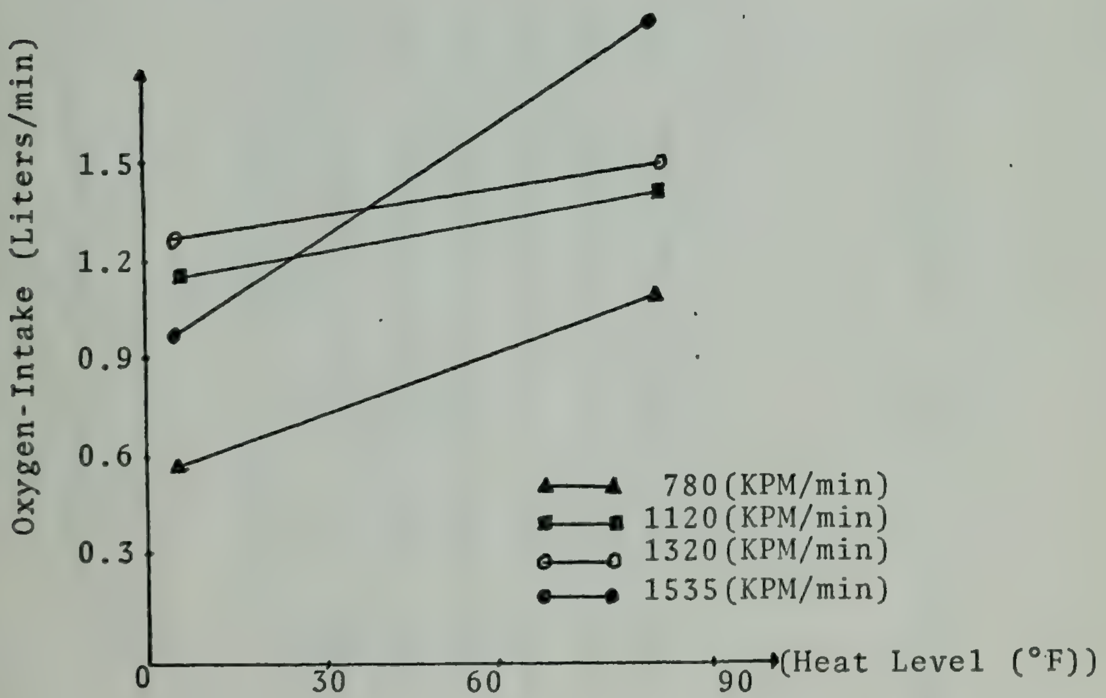

Figure IIB. Linear models for mean response oxygen-intake for constant work levels.

Table IIIC. Comparison Heat Levels Effecting Oxygen Consumption.

Overall Work Level	Comparison of Heat Levels	Vd	$t_{(computed)}$	$t^{(.95)}_{n_1+n_2=128}$	Difference Between Treatments at α = .05
	Heat level 95°F vs. Heat level 85°F	.00012	2.5	1.658	YES
	Heat level 95°F vs. Heat level 75°F	.000079	41.7		YES
Oxygen-Intake (liters per minute)	Heat level 95°F vs. Heat level 65°F	.00067	426		YES
	Heat level 85°F vs. Heat level 75°F	.00011	32.7		YES
	Heat level 85°F vs. Heat level 65°F	.00011	350		YES
	Heat level 75°F vs. Heat level 65°F	.000056	625		YES

Vd: Test statistics value (see Appendix A)

Table IIID. Comparison Work Levels Effecting Oxygen-Consumption.

Overall Heat Level	Comparison of Work Levels (RPM/min)	Vd	$t_{(computed)}$	$t^{(.95)}_{n_1+n_2=128}$	Difference Between Treatments at α = .05
	Work level 1535 vs. Work level 1320	.00005	64	1.658	YES
	Work level 1535 vs. Work level 1120	.00018	3.66		YES
Oxygen-Intake (liters per minute)	Work level 1535 vs. Work level 780	.0013	1.68		YES
	Work level 1320 vs. Work level 1120	.0018	1.11		NO
	Work level 1320 vs. Work level 780	.0028	.71		NO
	Work level 1120 vs. Work level 780	.065	1.07		NO

Vd: Test statistic (see Appendix A).

Table IV. One Variable Regression Model(s) for Heart-Beat and Oxygen-Intake.

	Work Level	Linear Model for Heart-Beat	Linear Model for Oxygen-Intake
OVERALL HEAT LEVEL	780 KPM/min	Y = 59.2 + 0.3 (HEAT•L)	Y = 0.55 + 0.004 (HEAT•L)
	1120 KPM/min	= 72 + 0.23 (HEAT•L)	= 1.11 - 0.0016 (HEAT•L)
	1320 KPM/min	= 82.5 + 0.215 (HEAT•L)	= 1.03 + 0.0018 (HEAT•L)
	1535 KPM/min	= 70.2 + 0.55 (HEAT•L)	= 0.87 + 0.014 (HEAT•L)
	Heat Level		
OVERALL WORK LEVEL	95°F	Y = 50.6 + 0.045 (WORK•L)	Y = 0.27 + 0.0007 (WORK•L)
	85°F	= 46.2 + 0.042 (WORK•L)	= 0.48 + 0.0004 (WORK•L)
	75°F	= 55 + 0.032 (WORK•L)	= 0.61 + 0.0039 (WORK•L)
	65°F	= 47 + 0.04 (WORK•L)	= 0.21 + 0.0072 (WORK•L)

Heart-Beat (beats/min)
Work-Level (KPM/min)
Oxygen-Intake (liters/min)
Heat Level (°F)

Table V. Correlations Between Heart-Rate and Its Explanatory Variables in Model II.

Explanatory Variables	Correlation Coefficient (r) with Heart-rate
$(\text{Heat Level})^{\frac{1}{2}}$	0.269
$(\text{Heat Level})^2$	0.280
(Work Level)	0.833
$(\text{Work Level})^2$	0.851

Table VI. Correlations Between Oxygen-Consumption and its Explanatory Variables in Model II.

Explanatory Variables	Correlation Coefficient (r) with Oxygen-Consumption
(Heat Level)	0.116
$(\text{Heat Level})^2$	0.125
$(\text{Work Level})^{\frac{1}{2}}$	0.685
$(\text{Work Level})^2$	0.698

Table VII. Comparison for the Actual Heart-Rate and Estimated Values.

Heat Level $^{\circ}F$	Work Level KPM/min	Actual Heart-Beat #1	#2	#3	#4	Estimated Heart-Beat Model I	Model II
65	780	82	78	81	78	80	75
	1120	90	87	93	84	93	89
	1320	96	105	105	96	103	93
	1535	117	108	110	102	115	104
75	780	82	84	78	82	79	79
	1120	82	97	94	88	92	91
	1320	86	100	98	95	101	99
	1535	96	111	111	110	114	108
85	780	81	78	88	82	82	81
	1120	93	87	96	87	95	94
	1320	96	90	110	93	105	103
	1535	111	115	119	120	117	111
95	780	93	90	84	91	90	85
	1120	99	99	89	98	103	98
	1320	108	112	96	112	112	106
	1535	129	123	126	120	125	114

Model I; Heart-Beat = 320.69 - 39.67(Heat Level)$^{1/2}$ + 0.0159(Heat Level)^2 + 0.00002(Work Level)^2

This model is significant at P = 0.5.

Model II; Heart-Beat = 23.73 + 0.325(Heat Level) + 0.0398(Work Level)

This model is significant at P = 0.05.

Table VIII. Comparison for the Actual Oxygen-Consumption and Estimated Values.

Heat Level °F	Work Level KPM/min	Actual Oxygen Consumption Subjects #1	#2	#3	#4	Estimated Oxygen Consumption Model I	Model II
65	780	0.76	0.77	0.80	0.73	0.83	0.80
	1120	0.90	1.05	1.15	0.87	0.96	1.02
	1320	1.18	1.13	1.33	1.78	1.06	1.15
	1535	1.25	1.19	1.37	1.32	1.18	1.30
75	780	0.86	0.97	1.05	0.90	0.83	0.80
	1120	0.87	1.03	1.10	1.05	0.96	1.02
	1320	1.02	1.09	1.21	1.25	1.06	1.15
	1535	1.05	1.26	1.77	1.34	1.18	1.30
85	780	0.67	0.58	0.63	0.62	0.83	0.80
	1120	1.09	0.86	0.78	0.86	0.96	1.02
	1320	1.16	1.01	1.05	1.05	1.06	1.15
	1535	1.21	1.15	1.34	1.19	1.18	1.30
95	780	1.00	0.67	1.15	0.85	0.83	0.80
	1120	1.02	0.82	1.15	1.05	0.96	1.02
	1320	1.31	1.18	1.30	1.48	1.06	1.15
	1535	1.51	1.33	1.55	1.46	1.18	1.30

Model I; Oxygen-Intake = $0.709 + 10^{-7}(\text{Work Level})^2$

This model is significant at $P = 0.05$.

Model II; Oxygen-Intake = $0.282 + 0.00066(\text{Work Level})$

This model is significant at $P = 0.05$.

APPENDIX A

Common slope test is conducted as follows:

let

$$d = |b_1 - b_2|$$

where b: slope regression coefficient of linear model

Hypothesis: $H_o: d = 0$

$H_1: d \neq 0$

Test Statistics: $$Vd = \frac{V_{Y1} + V_{Y2}}{\Sigma(x - \bar{x})^2}$$

$$t_{n_1+n_2} = \frac{d}{\sqrt{Vd}}$$

V_Y: Deviation from regression (computed from ANNOVA table produced as by-product of REGRE).

$\Sigma(x - \bar{x})^2$ is based on 64 data points and uses the REGRE to compute the σ for each independent variable.

$$\Sigma(x - \bar{x})^2 = (n-1)\sigma^2$$

APPENDIX B

DATA COLLECTED FROM EXPERIMENT

Subject #	Heat Level °F	Work Level KPM/min	Oxygen-Intake Liters/min	Heart-Beat Beats/min
1	65	780	0.76	82
		1120	0.90	90
		1320	1.18	96
		1535	1.25	117
2		780	0.77	78
		1120	1.00	87
		1320	1.13	105
		1535	1.19	108
3		780	0.79	81
		1120	1.05	93
		1320	1.33	105
		1535	1.37	110
4		780	0.73	78
		1120	1.15	84
		1320	1.28	96
		1535	1.32	102
1	75	780	0.86	82
		1120	0.87	82
		1370	1.02	86
		1535	1.05	96
2		780	0.97	84
		1120	1.03	97
		1320	1.09	100
		1535	1.26	111
3		780	1.05	78
		1120	1.10	94
		1320	1.21	98
		1535	1.27	111
4		780	0.90	82
		1120	1.05	88
		1320	1.25	95
		1535	1.34	110
1	85	780	0.67	81
		1120	1.09	93
		1320	1.16	94
		1535	1.21	111
2		780	0.58	78
		1120	0.86	87
		1320	1.01	90
		1535	1.15	115
3		780	0.63	88
		1120	0.73	96
		1320	1.05	110
		1535	1.34	119

Data from experiment continued.

4	85	780	0.07	82
		1120	0.86	87
		1320	1.05	93
		1535	1.19	120
1	95	780	1.15	93
		1120	1.15	99
		1320	1.30	108
		1535	1.55	129
2		780	1.00	90
		1120	1.02	99
		1320	1.31	112
		1535	1.51	123
3		780	0.67	84
		1120	0.82	89
		1320	1.18	96
		1535	1.33	126
4		780	0.85	91
		11 0	1.05	98
		1320	1.48	112
		1535	1.46	120

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